The Influence of Viability, Independence, and Self-Governance on Trust and Public Acceptance of Uncrewed Air Vehicle Operations

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Trust is expected to be a critical construct that drives successful use of advanced air mobility (AAM) technologies. As yet, though, the role of trust in human-autonomy interaction is underexplored. Kaber (2018) argues that autonomy requires the highest level of three independent dimensions -- viability, independence, and self-governance. The present study examined whether trust varies across the three dimensions of autonomy under varying levels of risk. Participants in the high-risk group read a series of vignettes on a drone that delivers medical supplies over a city where the current study was conducted. Participants in the low-risk group read a series of vignettes on a drone that delivers fast food over a fictitious city. Each vignette described a drone that is either autonomous (i.e., possesses all dimensions) or automated (i.e., one of the dimensions is compromised). Results imply that the three dimensions of autonomy do not equally influence human-technology trust and behavior.

INTRODUCTION

Advanced air mobility (AAM) is expected to play an integral part in future transportation safety by enabling mobility of goods and people within rural and urban areas (Patterson, 2021). The actual implementation of AAM requires advanced technologies such as electric propulsion, computer systems, and positioning systems (National Academies of Sciences, Engineering, and Medicine, 2020). For example, AAM technology will transform mobility of medical supplies via autonomous drones (Sigari & Biberthaler, 2021) and people via autonomous aircraft with electric vertical take-off and landing (eVTOL) capabilities. As such, AAM operations will involve sophisticated autonomous systems that perform varying tasks such as piloting and navigating air vehicles (Chancey et al., 2021) and support seamless interactions between human operators and multiple aircraft equipped with increasingly autonomous systems (Chancey et al., 2023).

The literature on human-automation interaction, however, indicates that human operators can use automation counterproductively by either misusing unreliable automation or disusing reliable automation (Parasuraman & Riley, 1997). Trust is one construct that underlies inefficient automation use such that operators who distrust reliable automation could result in disuse of reliable automation whereas operators who mistrust unreliable automation could result in misuse of unreliable automation (Lee & See, 2004).

Despite ample evidence that trust is a crucial factor that drives human-automation interaction, research on how trust influences interaction between humans and *autonomy*, an agent that is independent, self-governing, and viable (Kaber, 2018), is scarce. The present pilot work examined how trust varies across mock scenarios under different levels of risk and functionalities of autonomous/automated drones in an in-person survey.

Trust in Automation

Literature has emphasized the role of trust in human-automation interaction (Bailey & Scerbo, 2007; Bliss & Dunn, 2000; Chancey et al., 2017, 2021; Hoff & Bashir, 2015; Karpinsky et al., 2018; Lee et al., 2021; Lee & See, 2004; Muir, 1994; Sato et al., 2020, 2022; Yamani et al., 2020). Trust is commonly defined as “an attitude that an agent will help achieve an individual’s goals in a situation characterized by uncertainty and vulnerability” (Lee & See, 2004, pp. 51). Building on earlier works on interpersonal trust (Barber, 1983; Rempel et al., 1985) and human-automation trust (Muir, 1994; Muir & Moray, 1996), trust is often conceptualized as an attitude that evolves based on information on the automation’s behavior (i.e., performance), the automation’s algorithmic mechanism (i.e., process), and the system designer’s intention for developing the automation (i.e., purpose; Lee & See, 2004).

Researchers have identified several factors that influence performance, process, and purpose (Chancey et al., 2017; Karpinsky et al., 2018; Sato et al., 2020). For example, Sato et al. (2020) examined whether perceived risk modulated the effect of task load on trust. In the study, participants in the high-risk group were instructed that they would redo the experiment if they performed poorly, but participants in the low-risk group did not receive such instruction. Results indicated that performance-based trust increased when participants perceived high risk under high task load condition. Sato et al.’s (2020) findings support Mayer et al.’s (1995) model of trust which postulates that risk is a moderating factor on the influence of trust on later behaviors (see also Stuck et al., 2022, on discussion of risk). Of current interest is to study whether trust levels vary differently when interacting with autonomy rather than automation under different levels of risk.

Autonomy

In many professional domains such as modern surface and air transportation systems and healthcare, recent technological advancement has the potential to shift technologies from automation to autonomy. Yet, autonomy has been vaguely defined, complicating operational and functional differences between automation and autonomy. Kaber (2018) characterized autonomy as having three dimensions including *viability*, *independence*, and *self-governance*. Viability refers to the agent's ability to carry out basic functions in the environment. Independence refers to the agent's capacity to perform a task without other agents' assistance. Self-governance refers to the agent's capability to freely set a goal and devise an operational plan. According to Kaber (2018), an agent is considered autonomy *only if* an agent achieves the highest level of all three dimensions. Conversely, an agent is considered automation when one of the three dimensions does not reach the highest level. To facilitate better human-autonomy teaming in AAM operations, the current study examined how different dimensions of autonomy influence trust under risk.

Current Study

The current study is an exploratory work that examines whether trust differs between situations involving automation or autonomy by manipulating one of the three dimensions of autonomy in each scenario (i.e., viability, independence, and self-governance). Participants were asked to read a series of four different vignettes that describe a drone that delivers supplies over a city. The drone is either autonomous (i.e., possesses all dimensions) or automated (i.e., one of the dimensions is compromised). Additionally, the current study examined whether risk influenced trust towards a drone that is autonomous or automated. Risk was manipulated to be either high or low by changing the supplies to deliver (medical supplies or fast food, respectively) and the name of the city (Norfolk or Armidale, respectively). Following Mayer et al.'s (1995) and Sato et al.'s (2020) work, trust is expected to be higher in the high-risk condition than the low-risk condition.

METHOD

Participants

Forty-four undergraduate students (36 females and 8 males, M = 18.86 years, SD = 1.29 years) were recruited from Old Dominion University. Participants received research credits for participation.

Design

The current study employed a 2 × 4 split-plot factorial design with Risk as a between-subjects factor (High vs. Low) and Scenario as a within-subjects factor (Autonomy, Automation without Viability, Automation without Independence, vs. Automation without Self-governance).

Scenario

Scenarios were rendered within the context of numerous drones delivering goods over a densely populated area. Scenarios either involved an autonomous or an automated drone. Scenarios involving drones with Automation contained selective violations of the three assumptions of autonomy: viability, independence, or self-governance. Table 1 provides a description for each scenario. The context of the scenario varied between the two risk groups. Specifically, the scenarios used in the high-risk group assumed that the drones deliver medical supplies over the city of Norfolk (where the participants participated in the current study) whereas those in the low-risk group assumed that the drones deliver fast food over a fictitious city called Armidale. Table 2 presents a description of a scenario for each risk group.

Table 1. A description of each type of drones. A statement with an asterisk indicates a violation of one of the three dimensions of autonomy: viability, independence, and self-governance.

Types of Drones	***Description***
Autonomy	• The drones are capable of flying in stormy weather conditions. • The drones do not require someone to monitor the operations during the flight. • The drones automatically optimize its routes based on relative urgency of goods.
Automation without Viability	• The drones are vulnerable to stormy weather conditions. * • The drones do not require someone to monitor the operations during the flight. • The drones automatically optimize its routes based on relative urgency of goods.
Automation without Independence	• The drones are capable of flying in stormy weather conditions. • The drones require someone to monitor the operations during flight. * • The drones automatically optimize its routes based on relative urgency of goods.
Automation without Self-governance	• The drones are capable of flying in stormy weather conditions. • The drones do not require someone to monitor the operations during the flight. • The drones do not automatically optimize its routes based on relative urgency of goods. *

Table 2. Scenarios for High Risk group and Low Risk group.

Groups	***Scenario***
High Risk	These drones are being developed for public use flying over the City of Norfolk. In the area, there are public universities, city downtown, shopping center and military base. The drones frequently traverse over ODU in the area. The city of Norfolk is rolling out a new training program to transport medical supplies using drones. These drones will be frequently traversing over ODU with potentially 100s of daily operations. We are trying to assess public perceptions for these drone operations, which have some specific capabilities.
Low Risk	These drones are being developed for public use flying over the City of Armidale. In the area, there are public universities, city downtown, shopping center and military base. The drones frequently traverse over Armidale University in the area. The city of Armidale is rolling out a new training program to transport fast food using drones. These drones will be frequently traversing over Armidale University with potentially 100s of daily operations. We are trying to assess public perceptions for these drone operations, which have some specific capabilities.

Procedure

Participants completed an informed consent and a demographics questionnaire. Participants were then randomly assigned into the high-risk group or the low-risk group. Participants read four different vignettes about each type of drone on a piece of laminated paper in a random order. After participants read each vignette, they completed four questionnaires on their trust perception, perceived risk, behavioral intention, usefulness, and ease of use. Upon completion of the experiment, participants received research credits for participation. Each session took approximately 15 minutes.

Dependent Variables

Trust. Chancey et al.'s (2017) trust questionnaire consisted of 13 items that measure the three bases of trust on a 12-point Likert scale ranging from 1 (*not descriptive*) to 12 (*very descriptive*). These items were divided into three subsets including performance-based trust (minimum score = 5, maximum score = 60), process-based trust (minimum score = 5, maximum score = 60), and purpose-based trust (minimum score = 3, maximum score = 36). Jian et al.'s (2000) trust questionnaire consisted of 12 items each measuring trust or distrust towards the automation on a 7-point Likert scale ranging from 1 (*not at all*) to 7 (*extremely*). Items pertaining to distrust towards automation were reverse coded to measure overall trust (minimum score = 12, maximum score = 84).

Perceived Risk. Chancey et al.'s (2017) modified risk questionnaire comprised of 5 items on a 12-point Likert scale ranging from 1 (*not descriptive*) to 12 (*very descriptive*). These items were summed together to gauge the participant's perceived risk (minimum score = 5, maximum score = 60).

Behavioral Intention. A modified version of Rahman et al.'s (2017) questionnaire was used to assess behavioral intention. The questionnaire comprised of 3 items on a 7-point Likert scale ranging from 1 (*strongly disagree)* to 7 (*strongly agree*). The summation of these items will reflect the participant's behavioral intent (minimum score = 3, maximum score = 21).

Usefulness. Rahman et al.'s (2017) questionnaire was modified to assess usefulness of a drone. Specifically, the questionnaire consists of 4 items on a 7-point Likert scale ranging from 1 (*strongly disagree)* to 7 (*strongly agree*). These items will be summed together to assess the usefulness of the drone (minimum score = 4, maximum score = 28).

Ease of Use. Adapted from Rahman et al.'s (2017) questionnaire, the questionnaire comprised of 4 items on a 7-point Likert scale ranging from 1 (*strongly disagree)* to 7 (*strongly agree*). The sum of these items will reflect participant's ease of use towards a drone (minimum score = 4, maximum score = 28).

RESULTS

A series of 2 × 4 split-plot factorial analyses of variance (ANOVAs) was conducted to examine the impact of Risk and Scenarios on perceived risk, trust, behavioral intention, usefulness, and ease of use. Alpha level of .05 was adopted to indicate statistical significance. One participant withdrew from the study due to time constraints. Therefore, data from the remaining 43 participants (35 females and 8 males, M = 18.88 years, SD = 1.29 years) were included in the analyses.

Assumption Check

Prior to the analysis, assumption checks were conducted to ensure that the data had no outliers and the assumptions of normal distribution, homogeneity of variance, and sphericity were met. First, we created a boxplot for each dependent measure and applied the 1.5 interquartile range (IQR) rule to identify potential outliers. Visual inspection of the data indicated that each dependent measure had 1-5 outliers in the data. Therefore, a sensitivity analysis was conducted by running a split-plot factorial ANOVA with and without the outliers. Sensitivity analysis indicated that the outliers did not influence over the general pattern of the data, and thus all the data were included in the subsequent analyses. Second, Shapiro-Wilk tests were conducted to check for normality. Shapiro-Wilk tests indicated that all dependent measures were normally distributed. Third, Levene's tests were conducted to check for homogeneity of variance. Levene's tests indicated that all dependent measures had equal variances. Finally, a Mauchley's test for sphericity was conducted to check for sphericity. The analysis indicated a violation of sphericity for Jian et al.'s (2000) trust score, Chancey et al.'s (2017)

purpose-based trust score, behavioral intention, usefulness, and ease of use. Therefore, the present study applied a Greenhouse-Geisser correction to the degrees of freedom for the respective dependent measures.

Perceived Risk

None of the effects were statistically significant (all *p*s > .15).

Jian et al.'s (2000) Trust Score

Data indicated that trust scores significantly differed across the four scenarios, $F(2.49, 102.09) = 7.95$, $p < .001$, $\eta^2_G = 0.07$. Post-hoc Tukey honestly significant difference (HSD) tests indicated that participants rated higher trust in the Autonomy condition compared to the Automation without Viability condition ($M = 53.33$ vs. 47.84), $t(41) = 3.84$, $p = .002$, $d = 0.45$. Interestingly, participants rated higher trust in the Automation without Independence condition than the Automation without Self-governance condition ($M = 56.28$ vs. 49.47), $t(41) = -2.99$, $p = .024$, $d = 0.57$, and the Automation without Viability condition ($M = 56.28$ vs. 47.84), $t(41) = -4.44$, $p < .001$, $d = 0.70$. Data indicated no statistical difference for the remaining effects (*p*s > .95). Figure 1 presents the mean trust score across different types of drones.

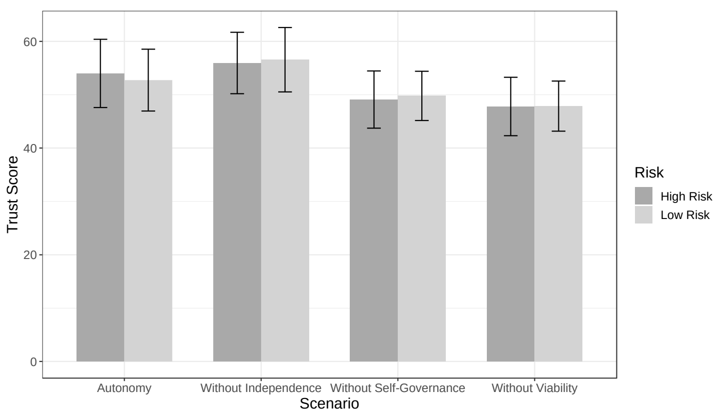

Figure 1. Mean trust scores for each type of drones. Error bars represent 95% confidence intervals.

Chancey et al.'s (2017) Trust Score

None of the effects were statistically significant (all *p*s > .12).

Behavioral Intention

Results indicated that behavioral intention varied across the four scenarios, $F(2.52, 103.32) = 8.02$, $p < .001$, $\eta^2_G = 0.05$. Post-hoc Tukey HSD tests indicated that participants rated higher behavioral intention in the Autonomy condition than the Automation without Self-governance condition, $t(41) = 3.62$, $p = .004$, $d = 0.45$, and the Automation without Viability condition, $t(41) = 3.14$, $p = .016$, $d = 0.44$. Additionally, participants rated higher behavioral intention in the Automation without Independence condition compared to the Automation without Self-governance condition, $t(41) = -3.15$, $p = .015$, $d = 0.46$, and the Automation without Viability condition, $t(41) = -3.44$, $p = .007$, $d = 0.45$. Data indicated no statistical significance for the remaining effects (*p*s > .76).

Usefulness

Participants' rating of usefulness differed across the four scenarios, $F(2.58, 105.78) = 12.39$, $p < .001$, $\eta^2_G = 0.09$. Post-hoc Tukey HSD tests indicated that participants rated higher usefulness in the Autonomy condition compared to the Automation without Self-governance condition, $t(41) = 3.62$, $p = .004$, $d = 0.64$, and the Automation without Viability condition, $t(41) = 3.14$, $p = .016$, $d = 0.56$. Furthermore, participants rated higher usefulness in the Automation without Independence condition than the Automation without Viability condition, $t(41) = -3.44$, $p = .007$, $d = 0.61$, and the Automation without Self-governance condition, $t(41) = -3.15$, $p = .015$, $d = 0.69$. The remaining effects did not reach statistical significance (*p*s > .13).

Ease of Use

Data indicated that participants rated ease of use differently across the four scenarios, $F(2.04, 83.64) = 3.16$, $p = .046$, $\eta^2_G = 0.04$. Post-hoc Tukey HSD tests indicated that participants rated higher ease of use in the Automation without Independence condition compared to the Automation without Self-governance condition, $t(41) = -3.09$, $p = .018$, $d = 0.48$, and the Automation without Viability condition, $t(41) = -3.01$, $p = .022$, $d = 0.44$. The remaining effects were not statistically significant (*p*s > .29).

DISCUSSION

Despite the prospect of actualizing the AAM concept thanks to recent progress in automated technologies, human factors research on interactions between humans and AAM technologies remains scarce (yet see Chancey et al., 2023). Further, as AAM technologies, and other technologies, approach the level of autonomy, a limited number of human operators will be tasked to supervise multiple autonomous agents (e.g., multi-vehicle operations; Aubuchon et al., 2022), and a deeper understanding of human-autonomy interaction and teaming is necessary for ensuring seamless integration and interaction between humans and autonomous technologies. To this end, the current pilot study aimed to explore how trust, perceived risk, and factors that determine operator behavior (i.e., intention to use, ease of use, usefulness) are affected by descriptions of human-technology interactions across various scenarios.

Overall, the participants exhibited greater levels of behavioral intent and usefulness toward autonomous drones than those that lack self-governance and those that are susceptible to physical disturbances. Interestingly, these scores were also higher in the scenario where drone operation is not independent of humans, suggesting that human users may in some cases prefer technologies that they can work together with rather than those that function independently. Yet, future research should further examine whether these behavioral predictors influenced by the self-governance and viability dimensions determine their technology acceptance and use.

Trust scores mirror this pattern of responses. That is, on Jian et al. (2000) questionnaire, but not in Chancey et al. (2017) questionnaire interestingly, trust scores were higher in the scenarios where drones were either autonomous or dependent to human users compared to the others. This implies that technologies that are not fully autonomous but still requires some form of human input for the control do not necessarily impede their trust toward the technology, and in turn may affect behavioral outcomes. To fully test the relationships found in the current study, future studies should use a structural equation modeling analysis with a larger sample size. In addition, the current risk manipulation was not effective, perhaps because the participants did not readily recognize their immediate risk imposed by the verbal description.

In summary, the current survey study found that trust and other behaviorally predictive measures in relation to hypothetical drone technologies may remain similar even when the technology is not considered autonomous but automation with a need of human intervention. However, human-technology trust is hampered when the drone is either not viable or self-governing, suggesting that the three dimensions of autonomy defined by Kaber (2018) do not equally influence human-technology trust and, possibly, behavior.

PRACTICAL TAKEAWAY

- Advanced technologies are shifting from automation to autonomy, necessitating researchers to understand the role of trust in human-autonomy teaming. Yet the distinction between autonomy and automation is unclear.
- This survey study examined trust and behavioral predictors towards an autonomous drone that possesses all autonomy dimensions described by Kaber (2018; i.e., viability, independence, and self-governance) and an automated drone that lacks one of the dimensions.
- Participants rated higher levels of trust, behavioral intent, and usefulness towards an automated drone without independence than an automated drone without self-governance and viability, suggesting that the three dimensions do not equally influence trust and, possibly, operator behaviors.

ACKNOWLEDGEMENT

This research was supported by a Cooperative Agreement (NIA.COOP.05.202075 – 202075) to Old Dominion University (PI Yamani) from NASA Langley Research Center. The views expressed are those of the authors and do not necessarily reflect the official policy or position of NASA or the U.S. Government.

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